

## Apparatus in a Drill String

### DESCRIPTION

#### [Para 1] FEDERAL SPONSORSHIP

[Para 2] This invention was made with government support under Contract No. DE-FC26-01NT41229 awarded by the U.S. Department of Energy. The government has certain rights in the invention.

#### [Para 3] CROSS REFERENCE TO RELATED APPLICATIONS

[Para 4] The present application is a continuation-in-part of co-pending U.S. Patent Application Serial No. 10/710,936 filed on August 13, 2004, which is herein incorporated by reference. U.S. Application Serial No. 10/710,936 is a continuation-in-part of U.S. Patent Application Serial No. 10/212,187 filed on August 5, 2002, which is herein incorporated by reference.

#### [Para 5] BACKGROUND OF THE INVENTION

[Para 6] This invention relates to an apparatus in a drill string. Specifically, this invention is a spirally welded metal tube having its original diameter sufficiently reduced by the formation of non-uniform protrusions on its surface so that it may be inserted into the bore of an internally upset drill pipe. The spirally welded metal tube is disposed within the drill pipe, and then expanded to conform to the inside surface of the pipe. The protrusions allow the tube to be expanded to at least its original diameter without rupturing the wall of the tube.

[Para 7] The idea of putting a metal tube as a liner into a drill pipe for the purpose of improving the corrosion resistance of the drill pipe and for providing a passageway for electrical conductors and fluid flow is not new. Those who are skilled in the art are directed to the following disclosures as references for installing a metal tube in a drill pipe.

[Para 8] U.S. Patent No. 2,379,800, to Hare, incorporated herein by this reference, disclosed the use of a protective shield for conductors and coils running along the length of the drill pipe. The shield served to protect the conductors from abrasion that would be caused by the drilling fluid and other materials passing through the bore of the drill pipe.

[Para 9] U.S. Patent No. 2,633,414, to Boivinnet, incorporated herein by this reference, disclosed a liner for an autoclave having folds that allowed the liner to be installed into the autoclave. Once the liner was installed, it was expanded against the inside wall of the autoclave using hydraulic pressure.

[Para 10] U.S. Patent No. 5,311,661, to Zifferer, incorporated herein by this reference, teaches a method for forming corrugations in the wall of a copper tube. The corrugations are formed by drawing or pushing the tube through a system of dies to reduce the diameter of the end portions and form the corrugations in center portion. Although the disclosure does not anticipate the use of a corrugated liner in drill pipe or other downhole component, the method of forming the corrugations is readily adaptable for that purpose.

[Para 11] U.S. Patent No. 5,517,843, to Winship, incorporated herein by this reference, discloses a method of making an upset end on metal pipe. The method of the reference teaches that as the end of the metal tube is forged, i.e. upset, the wall thickness of the end of the pipe increases and inside diameter of the pipe is reduced. The upsetting process, therefore, results in an overall changing topography along the inside wall of the drill pipe.

[Para 12] U.S. Patents Numbers 4,865,127; and 6,354,373 and Publication Number 2003/0178197 disclose lining a production well or a well bore. U.S. 5,390,742 to Dines, et al. discloses a patch for a longitudinally spaced series of tubular nipple structures installed in a well flow conductor operatively extending through a subterranean well bore. The walls of drill pipe and of production nipples require different characteristics. A drill pipe must be sufficiently strong to withstand the rotary motion and drilling strains experienced by a drill string, while the nipple comprises thinned walls such that a perforating gun may more easily rupture the wall.

[Para 13] U.S. Application Serial Number 10/707,232 filed by the applicants of the present invention on Nov. 29, 2003 discloses a liner insertable into the central bore of a downhole tool which includes a resilient material rolled into a substantially cylindrical shape. The outside diameter of the liner is variable to allow the liner to be inserted into a narrowed bore of the downhole tool near the box end or pin end. Once past the narrowed bore, the outside diameter of the liner self-expands within the central bore of the downhole tool.

[Para 14] U.S. Patent Number 4,029,932 discloses an apparatus for lining the interior of a metal pipe with a resilient material. A resilient material ribbon is fed from a roll external to the pipe and is drawn into the pipe by a first trolley which moves inside the pipe from one end of the pipe to the other. The first trolley shapes the ribbon into a spiral with overlapping edges. A laser beam is directed along the pipe and is redirected by a second trolley, which moves in synchronism with the first, towards the region at which the ribbon is being laid down against the pipe, the laser beam serving to weld overlapping edge regions of ribbon to each other. Special weld patterns are disclosed for preventing the leaks through the lining even in the presence of anticipated weld flaws.

#### [Para 15] BRIEF SUMMARY OF THE INVENTION

[Para 16] An apparatus in a drill string comprises an internally upset drill pipe. The drill pipe comprises a first end, a second end, and an elongate tube intermediate the first and second ends. The elongate tube and the ends comprising a continuous inside surface with a plurality of diameters. A conformable spirally welded metal tube is disposed within the drill pipe intermediate the ends thereof and terminating adjacent to the ends of the drill pipe. The conformable metal tube substantially conforms to the continuous inside surface of the metal tube.

[Para 17] The metal tube may be made of a material selected from the group consisting of steel, stainless steel, titanium, aluminum, copper, nickel, chrome, molybdenum, compounds, mixtures, and alloys thereof. The apparatus may comprise a metal tube which is more corrosion resistant than

the drill pipe. The corrosion resistance may extend the utility of the drill pipe. Fluids traveling within the bore of the drill pipes may create a solution allowing electrons to pass between the metal tube and drill pipe. An electrically insulating material between the metal tube and the drill pipe may resist this galvanic corrosion between the metal tube and the drill pipe; thereby, preserving the apparatus.

[Para 18] The metal tube may comprise a non-uniform section which is expanded to conform to the inside surface of the drill pipe. The non-uniform section may comprise protrusions selected from the group consisting of convolutions, corrugations, flutes, and dimples. The non-uniform section extends generally longitudinally along the length of the metal tube. The spirally welded metal tube may be adapted to stretch as the drill pipes stretch. The metal tube may have a regular end portion that is free of the non-uniform section. The non-uniform section of the metal tube may extend spirally along the surface of the metal tube. The non-uniform section may also be intermediate the end portions of the tube.

[Para 19] The non-uniform section of the metal tube may be formed by using hydraulic pressure, by roll forming, or by stamping. More than one die may be used to form the non-uniform section of the metal tube. A rough outside surface of the metal tube may help in bonding the metal tube to the inside surface of the drill pipe. The metal tube may be expanded inside the drill pipe by using hydraulic pressure or by drawing a mandrel over the uniform section. The metal tube may be placed in the drill pipe before the drill pipe is added to the drill string. Preferably, the non-uniform section of the metal tube is expanded and compressed against the inside surface of the drill pipe.

[Para 20] The inside surface may comprise a transition region comprising a plurality of diameters and forming a convex region and a concave region in the inside surface of the drill pipe. It is believed, but not wanting to be bound by any theory, that the spiral weld of the liner increases the strength of the liner as it expands to conform against the concave region of the transition region. It is further believed that the force expanding the liner is felt by the spiral weld at an angle, which distributes the force over a portion length of the weld.

**[Para 21] BRIEF DESCRIPTION OF THE DRAWINGS**

**[Para 22]** Fig. 1 is a perspective view of a drill string suspended by a derrick.

**[Para 23]** Fig. 2 is a cross sectional view of the present invention.

**[Para 24]** Fig. 3 is an enlarged cross sectional view of an end of the present invention.

**[Para 25]** Fig. 4 is an enlarged cross sectional view of an end of the present invention.

**[Para 26]** Fig. 5 is a perspective view of an expanded metal tube.

**[Para 27]** Fig. 6 is a perspective view of the metal tube comprising a corrugated non-uniform section.

**[Para 28]** Fig. 7 is a perspective view of a metal tube having a dimpled non-uniform section.

**[Para 29]** Fig. 8 is a perspective view of a metal tube having an ovoid non-uniform section.

**[Para 30]** Fig. 9 is a perspective view of a metal tube having a concave non-uniform section.

**[Para 31]** Fig. 10 is a perspective view of a metal tube having a corrugated non-uniform section.

**[Para 32]** Fig. 11 is a perspective view of a metal tube having a spirally fluted non-uniform section.

**[Para 33] DETAILED DESCRIPTION OF THE INVENTION AND THE PREFERRED EMBODIMENT**

**[Para 34]** Fig. 1 shows an embodiment of a drill string 32 suspended by a derrick 30. The drill string 32 comprises a multiplicity of drill pipe 34 intermediate a bottom hole assembly 33 and a swivel 31. The bottom hole assembly 33 may comprise drill bits, hammers, sensors, and other tools that may aid in drilling. The swivel 31 may provide stability to the drill string 31. In one aspect of the invention the drill string 32 is capable of transmitting electrical signals from bottom hole assembly 33 or other points along the drill

string 32 to the surface. Such a system is disclosed in U.S. Patent Number 6,670,880 to Hall, et al, which is herein incorporated by reference.

[Para 35] Fig. 2 is a cross sectional view of the apparatus 35 comprising an internally upset drill pipe 34 with a conformable spirally welded metal tube 36 disposed within a central bore 53 of the drill pipe 34. Transition regions 38 comprising a plurality of diameters that lie intermediate a first diameter 39 and a second diameter 37 in both the pin end 54 and the box end 55 of the drill pipe 34. The second diameter is generally consistent along the elongate tube portion of the drill pipe 34. For clarity, the metal tube 36 is shown not fully expanded against the inside surface 40 of the drill pipe 34. However, as the metal tube 36 is fully expanded against the inside surface 40 of the drill pipe 34, the transition regions 38 serve to lock the metal tube 36 in place so that the metal tube 36 is not only held in position by being in compression against the inside surface 40, but is also locked in position by the transition region 38. A metal tube 36 thus installed into a drill pipe has many advantages, among them are the improvement of the hydraulic properties of the bore 53 of the pipe 34, as well as corrosion and wear resistance. The metal tube 36 comprises a spiral weld 60, which runs from pin end 54 to the box end 55 of the apparatus 35.

[Para 36] Fig. 3 is an enlarged view of the pin end 54 of Fig. 2. Once again for clarity, the metal tube 36 is depicted not fully expanded against the inside surface 40 of the pipe 34. In actuality, at this stage of expansion, where the metal tube 36 is not fully expanded, it is expected that the remains of the protrusions would still be visible. The protrusions would not be fully ironed out until the metal tube 36 is fully pressed against the inside surface 40 of the drill pipe 34. An outside surface 41 may make contact with the inside surface 40 of the drill pipe 34 when the metal tube 36 is fully expanded. The outside surface 41 may be rough helping to maintain contact with the inside surface 40. The transition region 38 may form a concave region 43 with the second diameter 37 of the inside surface 40. The transition region 38 may also form a convex region 44 with the first diameter 39 of the inside surface 40 of the drill pipe 34. A resilient ring 42 may fill the concave region 43 and reduce the

stress felt by the metal tube 36 when expanding, which stress may cause a portion of the metal tube 36 adjacent to the concave region 43 to tear.

[Para 37] It is believed, but not wanting to be bound by any theory, that the spiral weld 60 of the metal tube 36 increases the strength of the liner as it expands to conform against the concave region of the transition region. The force expanding the liner may be felt by the spiral weld 60 at an angle distributing the force over a greater portion of the weld 60. A spirally welded metal tube may be .04" thick and be purchased from Packless Metal Hose, Inc. located in Waco, TX. Alternatively, the liner may range from .02" to .12" thick for a metal tube with an upset, 5 - 7/8" double shouldered drill pipe obtainable from Grant Prideco, Houston, Texas.

[Para 38] Fig. 4 shows an electrically insulating material 52 intermediate the metal tube 36 and the drill pipe 34. The tube 36 and the pipe 34 may be made with differing materials; for example, a pipe that consists of 4100 series steel and a metal tube that consists of stainless steel; the intimate contact of the differing materials may induce a galvanic corrosive condition. In order to prevent galvanic corrosion, the metal tube 36 or the drill pipe 34, or both, may be coated with an electrically insulating material 52 that would form a barrier even when the metal tube 36 and the inside surface 40 of the pipe 34 come in contact with each other as shown in Fig. 4.

[Para 39] Fig. 5 is a view of the expanded metal tube 36 of the present invention. For clarity the tube is depicted outside the drill pipe 34. A non-uniform section 46 of the metal tube 36 has been expanded to accommodate the drill pipe 34 having a changing diameter in the transition region 38 and a smaller first diameter at end portions 51. For example, in order to provide a metal tube 36 for an upset, 5 - 7/8" double shouldered drill pipe obtainable from Grant Prideco, Houston, Texas, having a first diameter of approximately 4 1/4" and a second diameter of approximately 5", a 316 SS tube of approximately 33' in length and having a wall thickness of about 0.080" was obtained. A metal tube was drawn through a series of carbide forming dies at Packless Metal Hose, Waco, Texas, in order to draw down the outside diameter of the metal tube to about 4.120". At the same time, the carbide dies formed the

end portions 51 and the non-uniform section corrugations 47 (shown in Figs. 6–11). A metal tube 36 similar to that shown in Fig. 1 was then inserted into the drill pipe, and the assembly was placed inside a suitable press constructed by the applicants. The end 51 of the metal tube 36 were sealed using hydraulic rams that were also capable of flowing pressurized water into the metal tube 36. Once the metal tube 36 was completely filled with water, the pressure of the water was increased in order to expand the metal tube 36 to match the second diameter 37 of the drill pipe 34. At around 150 psi the protrusions 47 began to move or expand as was evidenced by expansion noises coming from inside the drill pipe 34. The pressure was increased to between 3500 and 5000 psi whereupon the expansion noises nearly ceased. The applicants concluded that at about this time the metal tube 36 was fully expanded against the inside surface 40 of the drill pipe 34. Pressure inside the metal tube 36 was then increased to above 10,000 psi where it is thought that the metal tube 36 was placed in compression against the inside surface 40 of the drill pipe 34. When the drill pipe 34 was removed from the press, visual inspection revealed that the metal tube 36 had taken on the general shape as depicted in Fig. 5, and that the metal tube 36 had been fully expanded against the inside surface 40 of the drill pipe 34. The applicant attempted to vibrate and remove the metal tube 36 but found that it was fixed tightly inside the drill pipe 34.

[Para 40] Fig. 6 is an illustration of a metal tube 36 comprising a spiral weld 60. The metal tube 36 comprises regular end portions 51 and a non-uniform section 46 comprising of intermediate protruded corrugations. In this figure, the protrusions 47 are longitudinally axial along the length of the metal tube 36. At the ends of each protrusion 47 are transition regions 56 that may generally correspond to the transitional regions 38 within the upset drill pipe 34. The wall thickness of region 56 may range from between about one half the wall thickness to greater than the thickness of the tube wall. Suitable metal materials for the metal tube 36 may be selected from the group consisting of steel, stainless steel, aluminum, copper, titanium, nickel, molybdenum, and chrome, or compounds or alloys thereof. The metal tube 36 is formed by providing a selected length of tubing having an outside



diameter at least as great as the desired finished diameter of the metal tube 36, and by drawing the metal tube 36 through one or more dies in order to decrease the outside diameter of the metal tube 36 and form the end portions 51 and corrugations. Alternatively, the convolutions are formable by metal stamping, hydroforming, or progressive roll forming.

[Para 41] In the process of forming the end portions 51 and corrugations, the outside diameter of the metal tube 36 is decreased so that it may be inserted into a drill pipe 34, where the first diameter 39 of the drill pipe 34 is smaller than the outside diameter 57 of the metal tube 36. Once the metal tube 36 is inside the drill pipe 34, the metal tube 36 is plugged and hydraulically or mechanically expanded to its desired diameter. The protrusions 47 in the tube 36 allow the metal tube 36 to expand to at least its original outside diameter 57 and beyond, if so desired, without over straining the material of the metal tube 36. In this fashion the metal tube 36 may accommodate the changing inside surface 40 of the drill pipe 34. Another method of expanding the tube 36 is depicted in U.S. Pat. 2,263,714, incorporated herein by this reference, which discloses a method of drawing a mandrel through a metal tube 36 in order to expand it against the inside surface 40 of a drill pipe 34. Although the reference does not anticipate a first and a second diameter 37, 39, the mandrel may be adapted, according to the present invention, to size the tube 36 to the desired configuration within the drill pipe 34.

[Para 42] Fig. 7 illustrates a metal tube 36 having end portions 51 and a non-uniform section 46 of dimpled protrusions 50 along the length of the metal tube 36. The dimples 50 may be positive or negative with respect to the surface of the tube 36. As depicted the dimples 50 are generally round in shape, but they may be ovoid or elongated as shown in Fig. 8, and the properties of Fig. 7 are applicable to the properties of Fig. 8, and vice versa, where the non-uniform section 46 of the tube 36 has ovoid protrusions 48. Although, the dimple pattern as shown is regular in both Figs. 7 and 8 along the longitudinal axis of the metal tube 36, alternative patterns are possible and may be beneficial. For example, the pattern may be spiral or the pattern

may consist of a combination of protrusion styles alternating within the border region.

[Para 43] Fig. 9 is a view of another non-uniform section 46 of the present invention provided in a metal tube 36 with a spiral weld 60. The protrusion 47 consists of a single corrugation along the full lengthwise axis of the tube 36. Multiple corrugations are possible, but a single corrugation may be adequate. This design may also be used in connection with the regular end portions 51. This modified "D" configuration is appealing for its simplicity in design, and yet it is capable of accommodating a drill pipe having a regular inside diameter. Tests by the applicants have shown that both thick and thin walled tubing, say between .010" and .120" benefit from the non-uniform section 46 of the present invention during expansion. Without the non-uniform section 46, FEA analysis has shown that the tube 36 will likely rupture before it is sufficiently expanded against the inside surface 40. The configuration depicted in Fig. 9 may be useful in situations where it is desired to place a conduit or conductor cable along the inside of the drill pipe 34. The protrusion 47 may provide a pathway for the conduit and would form itself around the conduit during expansion. Then, not only would the metal tube 36 benefit the performance of the drill pipe 34, but it would also serve to fix the conduit or cable in place and protect it from the harsh down hole environment.

[Para 44] Fig. 10 is a view of a non-uniform section 46 provided in a metal tube 36. The non-uniform section 46 consists of longitudinal corrugations that may or may not extend the full length of the metal tube 36. As depicted, the protrusion 47 are at regular intervals around the circumference of the metal tube 36, however, the applicants believe that an irregular pattern may be desirable depending on the configuration of the inside surface 40 against which the conformable spirally welded tube 36 will be expanded. The desired depth of the protrusions as measured perpendicularly from the crest of the outer-most surface to the inside diameter as represented by the inner most surface of the trough may be determined by the total expansion required of the metal tube 36. For example, if the metal tube 36 were to be installed into a drill pipe 34 having a uniform inside diameter, the protrusions 47 would not

have to be as deep as the protrusions 47 may need to be if the metal tube 36 were to be installed into a drill pipe 34 having an inside surface 40 with a varying diameter. For example, for a drill pipe 34 having a uniform inside diameter, the depth of the protrusions may be approximately equivalent to one half of the wall thickness of the metal tube 36 and be adequate to achieve sufficient expansion inside the drill pipe 34, depending on the number of protrusions and their proximity to each other. On the other hand, where the inside wall of the drill pipe 34 has a varying diameter, the protrusions may have to exceed the greatest variation between inside diameter irregularities. These are critical dimensions that are included within the teachings of the metal tube 36 of the present invention.

[Para 45] Fig. 11 is a view of the metal tube 36 of Fig. 10 modified so that the metal tube 36 exhibits a non-uniform section 46 along its length consisting of an inner wall 58 and an outer wall 59 made up of protrusions 47 that are formed into spiral flutes 45. This configuration would be useful in drill pipes 34 having uniform inside wall surfaces. The flutes 45 may be proportioned so that conduits and conductors may be disposed within the troughs and run along the full length of the drill pipe 34. Such conduits and conductors would then be protected from the harsh fluids and tools that are circulated through the pipe's bore 53. In cases where it would be desirable to control the flow of fluid through the bore 53 of the drill pipe 34, it may be desirable to expand the metal tube 36 in such a manner so that the form of the protrusions 47 remain in the inside wall 58 of the metal tube 36 after it has been fully expanded. The modified flow produced by the presence of protrusions 47 in the inner wall 58 of the drill pipe 34 would be beneficial in reducing boundary conditions that tend to reduce the efficient flow of fluid through the drill pipe 34.